THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

EVALUATION OF THE IMPROVED LINERBOARD CRACKING TESTER USING 69-POUND LINERS

Project 1108-29

Report Three

A Preliminary Report

to

TECHNICAL COMMITTEE

FOURDRINIER KRAFT BOARD INSTITUTE, INC.

November 19, 1963

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SUMMARY

Two previous reports have discussed the development of a tester for evaluating the score cracking potential of linerboard. Essentially, the test consists of folding the board over an anvil of known radius to induce tensile strains on the outside surface. The angle at which cracking is observed is measured. In the previous report a number of 90-pound liner samples were evaluated for their cracking angle and for their degree of cracking when used as the double-face liner of A-flute combined board. In general, it was noted that: a) the linerboard cracking tests appeared to be reasonably well related to the degree of combined board cracking, and b) useful relationships between the degree of combined board cracking and relative humidity were obtained.

The above work has been extended to a series of 69-pound liner samples in this report with essentially the same results although slightly different regression lines of the probability type were required for the two grades.

If work in progress involving 42-pound liners also gives encouraging results it is suggested that plans be made to:

1. Produce a number of working models of the tester for mill trial.

2. Continue investigations into the variables of the tester and the nature and magnitude of the strains induced in the folding operation of combined board.

3. To investigate the fiber and sheet characteristics which influence the foldability of linerboard.

INTRODUCTION

The initial results obtained in this study were described in Report 1 dated June 18, 1963. In general, attention was focused on a foldability tester of Institute design for determining the cracking potential of linerboard. The initial results indicated that the new tester exhibited some promise, however, additional requirements appeared desirable to permit better evaluations within individual grades of linerboard.

Improved clamps were made for the tester and the anvil heads over which the specimen is stretched were machined to have a 0.010-inch radius. Report 2 dated Sept. 12, 1963 discussed results obtained with the improved tester. In Report 2, 90-pound liner samples were evaluated as double-face liners and after lamination to single-faced board having a 90-pound liner. After scoring and folding, the degree of cracking of the combined board and the liner cracking angle were determined at 10, 20, 30, 40, and 50% R.F. Reasonably favorable correlation between combined board cracking and the liner cracking evaluations with the improved tester were obtained. In addition, analyses of the relationship between combined board cracking and relative humidity indicated that probability-type equations appeared to fit the data trends.

To gain further experience with the tester, it was thought desirable to carry out a similar analysis using 69 and 42-pound liners. As in Report 2, the range of cracking was increased by subjecting the linerboards before fabrication to heat or humidity to change their characteristics. Results obtained with the 69-pound liner samples are briefly summarized in this report.

MATERIALS

The physical characteristics of the 69-pound liner samples used are tabulated in Table I.

TABLE I

PHYSICAL CHARACTERISTICS OF 69-POUND LINER SAMPLES

Sample No.	Basis Weight, lb./M ft.	Caliper, pt.	Tensile, lb./in. In	Tensile, lb./in. Cross	Stretch, % In	Stretch, % Cross
2413	70.4	20.0	114.2	55.3	1.5	3.5
2419	69.3	20.0	130.6	55.6	1.8	4.8
2422	69.4	19.6	113.1	55.6	1.3	2.0
2426	72.4	19.9	126.4	62.2	1.9	3.3
2446	73.7	20.2	116.2	60.9	1.7	3.3
2459	69.5	21.8	118.0	55.2	1.8	3.8
2463	69.6	22.5	124.7	58.6	1.8	4.3
2489	73.0	20.9	130.0	59.0	1.6	3.0

All of the above samples were fabricated into double-faced board and evaluated for cracking at 10, 20, 30, 40, and 50% R.H. In addition, portions of each sample were treated as follows prior to the double-facing operation:

1. At least 72 hours exposure to 90% R.H. and 73°F. followed by preconditioning at less than 35% R.H. and conditioning at 50% and 73°F. prior to fabrication or evaluation.

2. At least 36 hours exposure at 125°C. followed by preconditioning and conditioning as noted in (1) abcve.

DOUBLE-FACING AND SCORING

Double-faced board was made by hand gluing sheets of the linerboard to a single-faced board corrugated on the Institute's experimental corrugator.

With the exception that a 90-pound liner was used as the single-face liner, the same conditions were used as specified in Report One.

FOLDING

As in the previous work, five sheets of board with 3-11 inch long panel scores per sheet were evaluated for cracking for each sample in each atmosphere. Thus, each percentage cracking value is based on an examination of 165 inches of scoreline. The folded board was taped together to standardize the viewing and handling conditions and the cumulative length of severe cracks was measured—a minimum length of 0.10 inch was used corresponding to a minimum percentage cracking of about 0.1%.

To increase crack visibility, a spray coating of flat black paint was used as described in the previous study. The length and occurrence of severe cracks was judged in comparison with a reference scoreline.

LINERBOARD FOLDABILITY TEST

Ten specimens of each linerboard sample were evaluated at each humidity level with the fold line at right angles to the machine direction. As in the case of the combined board samples, a spray coating of flat black paint was used to increase crack visibility. The rupture angle associated with the first appearances of a crack in the liner surface was measured. Efforts were also made to measure the angle associated with a more severe degree of cracking; however, these readings would have been in excess of the maximum angle permitted by the tester in the higher humidities. Therefore, the severe cracking criterion was discontinued; however, it may be tried in future work in an effort to improve and simplify the routine evaluation of linerboard.

DISCUSSION OF RESULTS

A tabulation of the combined board and linerboard cracking results may be found in Table II. As in the previous study both the combined board and linerboard tests exhibit the expected trends with folding humidity and fabrication treatment. For example, with increasing folding humidity, the degree of combined board cracking decreases and the linerboard cracking angle increases. Similarly, the samples heated at 125°C. prior to fabrication into combined board tended to exhibit increased combined board cracking and smaller linerboard cracking angles relative to the untreated samples.

RELATIONSHIP BETWEEN COMBINED BOARD CRACKING AND LINERBOARD CRACKING

In the previous report it was found that probability or exponential equations appeared to best fit the relationship between combined board cracking and the liner cracking angle. With this in mind, the combined board cracking data in per cent were transformed to standard deviation units (Y). The transformed values are tabulated in Appendix I. (Note: All 0% combined board cracking results were excluded from the analysis because they cannot be transformed into logarithms or standard deviation units.)

A comparison of linear, exponential, and probability-type correlations may be found in Table III for the 69-pound liner data. As may be noted in the table, the probability-type regression exhibited the best correlation with combined board cracking. A graph of the results in arithmetic probability type co-ordinates is shown in Fig. 1. As may be noted in Fig. 1, the over-all regression line for the 69-pound liner data is slightly displaced from the regression

TABLE II

COMBINED BOARD AND LINERBOARD CRACKING RESULTS
(Black coated)

Sample No.	Combined Board Cracking, %					Linerboard Cracking Angle, °				
	10% R.H.	20% R.H.	30% R.H.	40% R.H.	50% R.H.	10% R.H.	20% R.H.	30% R.H.	40% R.H.	50% R.H.
					Untreated					
2413	34.4	10.7	2.3	0.0	0.0	54.5	58.1	64.3	67.3	85.7
2419	31.0	9.4	1.2	0.1	0.0	51.2	56.6	62.4	65.6	75.4
2422	79.6	42.2	12.0	0.8	0.1	48.0	52.5	58.5	62.5	71.5
2426	23.3	9.8	0.6	0.1	0.0	51.4	59.0	64.6	70.4	82.9
2446	61.5	37.5	4.2	0.7	0.3	48.3	54.4	59.7	61.7	77.0
2459	52.0	19.0	5.7	0.1	0.0	49.7	54.7	60.4	63.5	76.0
2463	41.4	13.8	2.2	0.0	0.0	49.2	55.0	59.8	65.5	79.3
2489	79.2	45.9	10.9	2.0	0.2	46.5	49.6	57.4	63.4	76.4
					After High Humidity Relaxation Treatment					
2413	44.2	10.6	0.7	0.0	0.0	53.1	56.3	64.9	68.1	79.6
2419	30.4	4.2	0.9	0.0	0.0	54.4	56.4	66.8	71.9	74.7
2422	80.0	50.0	9.8	1.0	0.1	50.6	53.7	60.4	64.2	68.5
2426	29.3	3.1	0.3	0.0	0.0	55.9	60.4	69.3	72.0	81.3
2446	53.8	24.6	2.7	0.1	0.1	49.8	56.3	62.8	65.1	71.9
2459	76.3	31.3	1.6	0.3	0.0	51.3	57.9	66.6	71.7	78.5
2463	63.4	10.3	0.4	0.0	0.0	51.9	58.5	67.8	68.9	77.4
2489	82.8	37.4	6.6	1.8	0.0	50.8	57.7	61.8	62.6	75.1
					After Drying at 125°C. for 36 hr.					
2413	87.4	36.9	14.4	2.5	0.4	47.2	51.2	57.6	63.4	71.1
2419	66.6	27.2	8.0	0.8	0.1	48.0	52.7	56.1	60.4	67.9
2422	93.2	71.7	34.3	8.5	1.5	44.7	53.2	56.1	56.9	68.9
2426	66.6	43.0	5.4	2.6	0.4	47.7	54.4	56.7	62.7	67.5
2446	94.3	82.9	49.2	22.2	4.0	42.1	50.3	52.7	56.7	62.3
2459	96.4	74.6	23.4	15.0	1.1	44.2	51.0	54.2	58.3	67.6
2463	84.8	49.3	6.0	0.7	0.0	46.3	51.9	55.8	59.6	72.5
2489	98.1	90.7	36.3	28.7	13.7	40.1	46.4	51.6	52.8	61.5

Note: Linerboard cracking angle corresponding to initial observed crack.

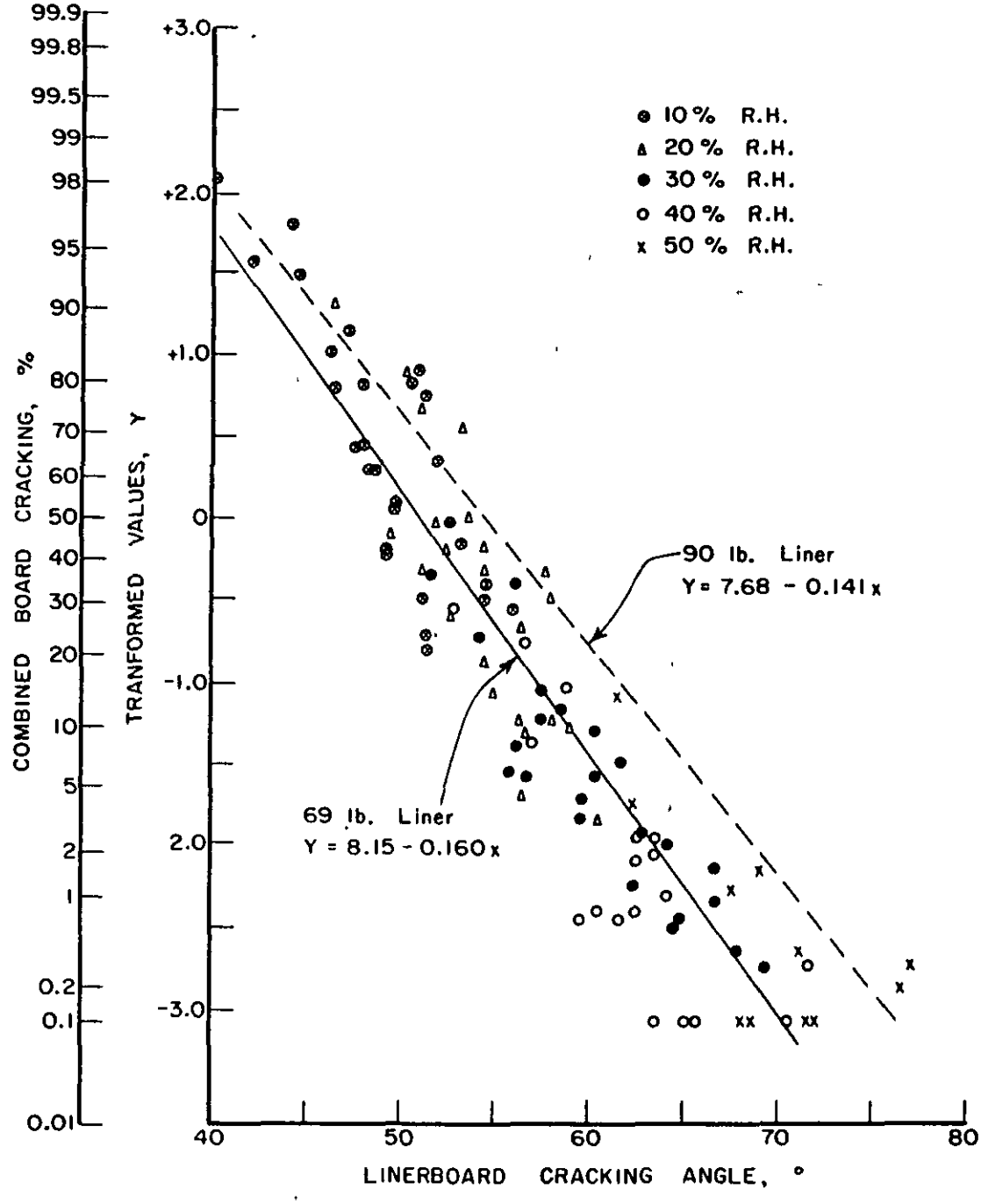

Fig. 1. Relationship Between Combined Board Cracking and the Liner Cracking Angle for 69 Pound Liner Samples (Arithmetic probability co-ordinates)

line for 90-pound liners and exhibits a slightly greater slope. These differences in slope and intercept between the 69 and 90-pound grades may reflect differences in caliper and, probably, shear characteristics. When data for 42-pound double-face liners (testing in progress) are available, it should be possible to clarify this.

TABLE III

CORRELATIONS OF COMBINED BOARD CRACKING AND THE LINER CRACKING ANGLE

(Composite 69-pound liner results--N = 102)

Equation No.	Type of Equation	Regression Equation	Correlation Coefficient
1.	Linear	$\underline{p} = 219.1 - 3.33\underline{x}$	0.85
2.	Exponential	$\text{Log } \underline{p} = 7.192 - 0.110\underline{x}$	0.91
3.	Exponential	$\text{Log } \underline{p} = 4.038 - 0.000,936\underline{x}^2$	0.91
4.	Probability	$\underline{Y} = 8.15 - 0.160\underline{x}$	0.93

Note: $\underline{p}$ = combined board cracking.

$\underline{Y}$ = combined board cracking, transformed to standard deviation units.

$\underline{x}$ = liner cracking angle, °.

The probability-type regressions were also performed using the data at each humidity level. These regressions are shown in Table IV. As may be noted, the correlations at each relative humidity level were reasonably high. They tended to be, however, somewhat lower than were obtained with 90-pound liners. This is probably due to the fact that lesser amounts of cracking tended to be obtained with the 69-pound liners in comparable conditions. This was particularly true at 40 and 50% R.H. where a number of combined board samples exhibited little or no severe cracking. It would be expected that estimates of minor amounts of cracking would be subject to considerable uncertainty.

TABLE IV

CORRELATION OF COMBINED BOARD CRACKING
AND THE LINERBOARD CRACKING TEST

Equation No.	Data Subdivision	N	Regression Equation[a]	Correlation Coefficient
			69-Pound Liners	
1	Over-all	102	$\underline{Y} = 8.15 - 0.160\underline{x}$	0.93
2	10% R.H.	24	$\underline{Y} = 8.89 - 0.172\underline{x}$	0.82
3	20% R.H.	24	$\underline{Y} = 10.47 - 0.201\underline{x}$	0.83
4	30% R.H.	24	$\underline{Y} = 6.70 - 0.138\underline{x}$	0.90
5	40% R.H.	18	$\underline{Y} = 6.54 - 0.140\underline{x}$	0.81
6	50% R.H.	12	$\underline{Y} = 3.97 - 0.094\underline{x}$	0.71
			90-Pound Liners[a]	
7	Over-all	70	$\underline{Y} = 7.68 - 0.141\underline{x}$	0.94
8	10% R.H.	14	$\underline{Y} = 10.03 - 0.192\underline{x}$	0.86
9	20% R.H.	14	$\underline{Y} = 9.71 - 0.175\underline{x}$	0.94
10	30% R.H.	14	$\underline{Y} = 6.14 - 0.111\underline{x}$	0.92
11	40% R.H.	14	$\underline{Y} = 6.37 - 0.125\underline{x}$	0.86
12	50% R.H.	14	$\underline{Y} = 4.99 - 0.104\underline{x}$	0.91

[a] $\underline{Y}$ = combined board cracking transformed to standard deviation units.

$\underline{x}$ = liner cracking angle, °.

To illustrate in another way the degree of relationship between the liner cracking angle and combined board cracking the over-all regression equations for the 69 and 90-pound liners [Equations (1) and (7) in Table IV] were used to compute percentage combined board cracking values. The calculated and observed values are compared in Tables V and VI for the 69 and 90-pound data, respectively. In general, while large discrepancies occur, reasonable agreement is attained in most instances—particularly with respect to sample ranking and humidity effects.

In brief summary, on the basis of these results, it appears that

1. The linerboard cracking test is reasonably well related to combined board cracking when either 69 or 90-pound liners are used as the double-face liner.

TABLE V

COMPARISON OF COMPUTED AND OBSERVED COMBINED BOARD CRACKING FOR 69-POUND SAMPLES

Sample No.	Combined Board Cracking, %														
	10% R.H.			20% R.H.			30% R.H.			40% R.H.			50% R.H.		
	Calculated[b]	Observed	Diff.	Calculated[b]	Observed	Diff.	Calculated[b]	Observed	Diff.	Calculated[b]	Observed	Diff.	Calculated[b]	Observed	Diff.
							Untreated								
2413	28.4	34.4	-6.0	12.5	10.7	+1.8	1.6	2.3	-0.7	0.4	0.0	+0.4	0.0[a]	0.0	0.0
2419	48.4	31.0	+17.4	18.1	9.4	+8.7	3.4	1.2	+2.2	0.9	0.1	+0.8	0.0[a]	0.0	0.0
2422	68.1	79.6	-11.5	40.1	42.2	-2.1	11.3	12.0	-0.7	3.2	0.8	+2.4	0.0[a]	0.1	-0.1
2426	47.2	23.3	+23.9	9.8	9.8	0.0	1.4	0.6	+0.8	0.1	0.1	0.0	0.0[a]	0.0	0.0
2446	66.3	61.5	+4.8	29.1	37.5	-8.4	8.1	4.2	+3.9	4.3	0.7	+3.6	0.0[a]	0.3	-0.3
2459	57.9	52.0	+5.9	27.4	19.0	+8.4	6.5	5.7	+0.8	2.2	0.1	+2.1	0.0[a]	0.0	0.0
2463	61.0	41.4	+19.6	25.8	13.8	+12.0	7.8	2.2	+5.6	1.0	0.0	+1.0	0.0[a]	0.0	0.0
2489	76.1	79.2	-3.1	58.3	45.9	+12.4	15.2	10.9	+4.3	2.3	2.0	+0.3	0.0[a]	0.2	-0.2
							Relaxed								
2413	36.3	44.2	-7.9	19.5	10.6	+8.9	1.3	0.7	+0.6	0.3	0.0	+0.3	0.0[a]	0.0	0.0
2419	29.1	30.4	-1.3	19.2	4.2	+15.0	0.6	0.9	-0.3	0.0[a]	0.0	0.0	0.0[a]	0.0	0.0
2422	52.0	80.0	-28.0	33.0	50.0	-17.0	6.5	9.8	-3.3	1.7	1.0	+0.7	0.2	0.1	+0.1
2426	21.5	29.3	-7.8	6.5	3.1	+3.4	0.2	0.3	-0.1	0.0[a]	0.0	0.0	0.0[a]	0.0	0.0
2446	57.1	53.8	+3.3	19.5	24.6	-5.1	2.9	2.7	+0.2	1.2	0.1	+1.1	0.0[a]	0.1	-0.1
2459	47.6	76.3	-28.7	13.4	31.3	-17.9	0.6	1.6	-1.0	0.0[a]	0.3	-0.3	0.0[a]	0.0	0.0
2463	44.0	63.4	-19.4	11.3	10.3	+1.0	0.4	0.4	0.0	0.2	0.0	+0.2	0.0[a]	0.0	0.0
2489	50.8	82.8	-32.0	14.0	37.4	-23.4	4.1	6.6	-2.5	3.1	1.8	+1.3	0.0[a]	0.0	0.0
							Heated								
2413	72.6	87.4	-14.8	48.4	36.9	+11.5	14.2	14.4	-0.2	2.3	2.5	-0.2	0.0[a]	0.4	-0.4
2419	68.1	66.6	+1.5	39.0	27.2	+11.8	20.3	8.0	+12.3	6.5	0.8	+5.7	0.3	0.1	+0.2
2422	84.1	93.2	-9.1	35.9	71.7	-35.8	20.3	34.3	-14.0	17.1	8.5	+8.6	0.2	1.5	-1.3
2426	69.8	66.6	+3.2	29.1	43.0	-13.9	17.9	5.4	+12.5	3.0	2.6	+0.4	0.4	0.4	0.0
2446	92.1	94.3	-2.2	54.0	82.9	-28.9	39.0	49.2	-10.2	17.9	22.2	-4.3	3.4	4.0	-0.6
2459	86.0	96.4	-10.4	49.6	74.6	-25.0	30.2	23.4	+6.8	11.9	15.0	-3.1	0.4[a]	1.1	-0.7
2463	77.0	84.8	-7.8	44.0	49.3	-5.3	21.8	6.0	+15.8	8.2	0.7	+7.5	0.0[a]	0.0	0.0
2489	95.8	98.1	-2.3	76.7	90.7	-14.0	45.6	36.3	+9.3	38.2	28.7	+9.5	4.6	13.7	-9.1

[a] Estimated percentage values less than 0.1 were taken equal to zero.

[b] Calculated from regression equation $Y = 8.15 - 0.160x$ where x is the liner cracking angle and Y is combined board cracking in standard deviation units. Y values were transformed to percentages using Table A, Appendix III of Reference (1).

TABLE VI

COMPARISONS OF COMPUTED AND OBSERVED COMBINED BOARD CRACKING FOR 90-POUND SAMPLES

Sample No	Combined Board Cracking, %														
	10% R H			20% R H			30% R H			40% R H			50% R H		
	Calculated[b]	Observed	Diff	Calculated[c]	Observed	Diff	Calculated[c]	Observed	Diff	Calculated[b]	Observed	Diff	Calculated[c]	Observed	Diff
Untreated															
2414	96 5	99 7	-3 2	92 6	96 1	-3 5	84 4	76 7	+7 7	40 9	37 5	+3 4	37 8	30 9	+6 9
2420	90 0	77 4	+12 6	65 5	53 5	+12 0	33 0	21 2	+11 8	0 9[a]	1 7	-0 8	3 6[a]	1 0	+2 6
2427	65 2	69 5	-4 3	29 8	33 4	-3 6	7 0	6 2	+1 4	0 0[a]	0 1	-0 1	0 0[a]	0 2	-0 2
2451	65 5	31 1	+34 4	24 8	17 1	+7 7	0 8	1 4	-0 6	0 0[a]	0 1	-0 1	0 1	0 1	0 0
2465	94 8	84 4	+10 4	72 6	69 7	+2 9	25 1	26 1	-1 0	12 5	2 7	+9 8	6 5[a]	2 2	+4 3
2491	68 1	53 0	+15 1	16 1	25 0	-9 9	0 6	4 8	-4 2	0 3	0 1	+0 2	0 0[a]	0 3	-0 3
Relaxed															
2414	97 3	99 9	-2 6	82 6	97 3	-14 7	34 6	65 3	-30 5	33 4	38 1	-4 7	26 8	21 8	+5 0
2420	80 5	78 3	+2 2	45 2	42 8	+2 4	8 7	11 0	-2 3	7 9	1 6	+6 3	5 5	1 5	+4 0
2427	49 2	49 3	-0 1	23 6	28 2	-4 6	0 6	3 1	-2 5	2 5	0 2	+2 3	0 2	0 1	+0 1
2465	93 7	81 6	+12 1	64 8	69 4	-4 6	10 2	21 9	-11 7	32 3	1 6	+30 7	2 6	0 5	+2 1
2491	62 6	47 1	+15 5	30 5	35 5	-5 0	0 5	5 4	-4 9	0 3	0 4	-0 1	0 1	0 2	-0 1
Heated															
2427	90 7	94 3	-3 6	79 1	88 9	-9 8	30 8	51 4	-20 6	15 6	34 2	-18 6	12 9	16 3	-3 4
2451	97 0	96 0	+1 0	77 0	92 9	-15 9	31 6	51 9	-20 3	35.6	39 1	-3 5	26 1	10 0	+16 1
2491	92 4	96.4	-4 0	70 2	90 8	-20 6	35 9	44 3	-8 4	23 9	17 6	+6 3	11 5	5 0	+6 5

[a] Estimated percentage values less than 0 1 were recorded as zero

[b] Calculated from regression equation $Y = 7\ 68 - 0\ 141x$ where x is the liner cracking angle and Y is the combined board cracking in standard deviation units Y values were transformed to percentages using Table A, Appendix III of Reference (1)

2. The relationship between the two quantities—combined board cracking and liner cracking angle—is best fitted by probability-type equations. At this time it appears that slightly different regression constants are required for the two grades.

EFFECT OF HUMIDITY ON COMBINED BOARD CRACKING

In the previous report it was shown that with 90-pound liners the relationship between the degree of combined board cracking and relative humidity was approximately linear when plotted using arithmetic probability co-ordinates. Similar graphs were prepared for the 69-pound samples of this study as shown in Fig. 2 through 7. Referring to the figures, it may be noted that essentially linear relationships were obtained for all the samples.

As in the previous report the transformed combined board cracking values ($\underline{Y}$) were correlated with relative humidity as shown in Table VII. In general, the slopes were roughly equal for all samples although Sample 2463 exhibited relatively high slopes for the relaxed and heated samples. It may be recalled that the 90-pound Sample 2464 laminated from two 42-pound plies exhibited a greater slope than the remaining samples. As a matter of interest, Sample 2463 was manufactured by the same mill.

A covariance analysis was carried out for a number of the samples to determine if the differences in slope were significant. In all cases examined, the slopes were not significantly different in view of the scatter of the data and the small number of points for each line. A similar analysis was carried out to test the differences in slope between samples with the same result. Thus, there is considerable justification for using an average slope for all the data.

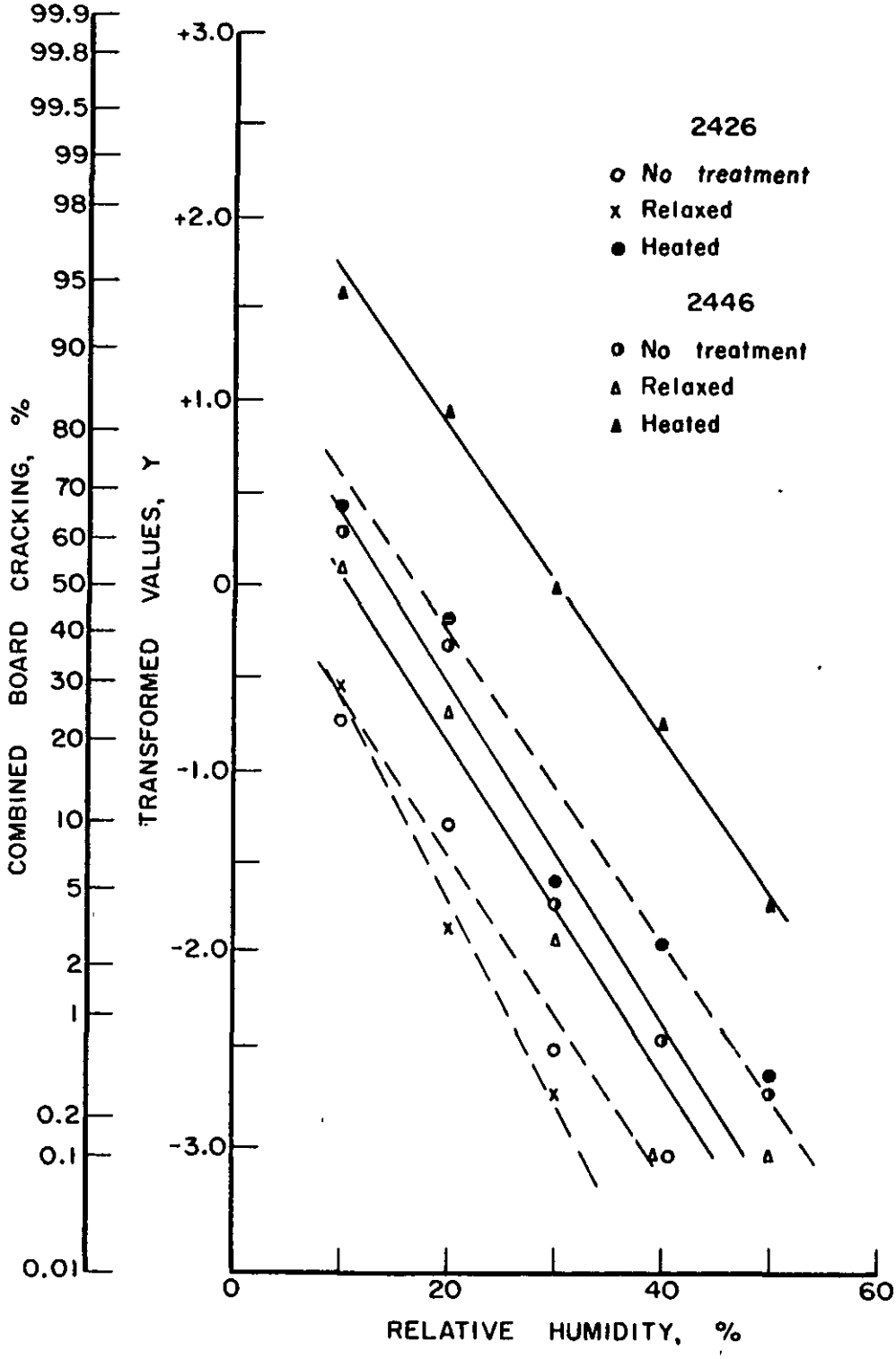

Fig. 2. Effect of Relative Humidity on Combined Board Cracking for Samples 2426 and 2446

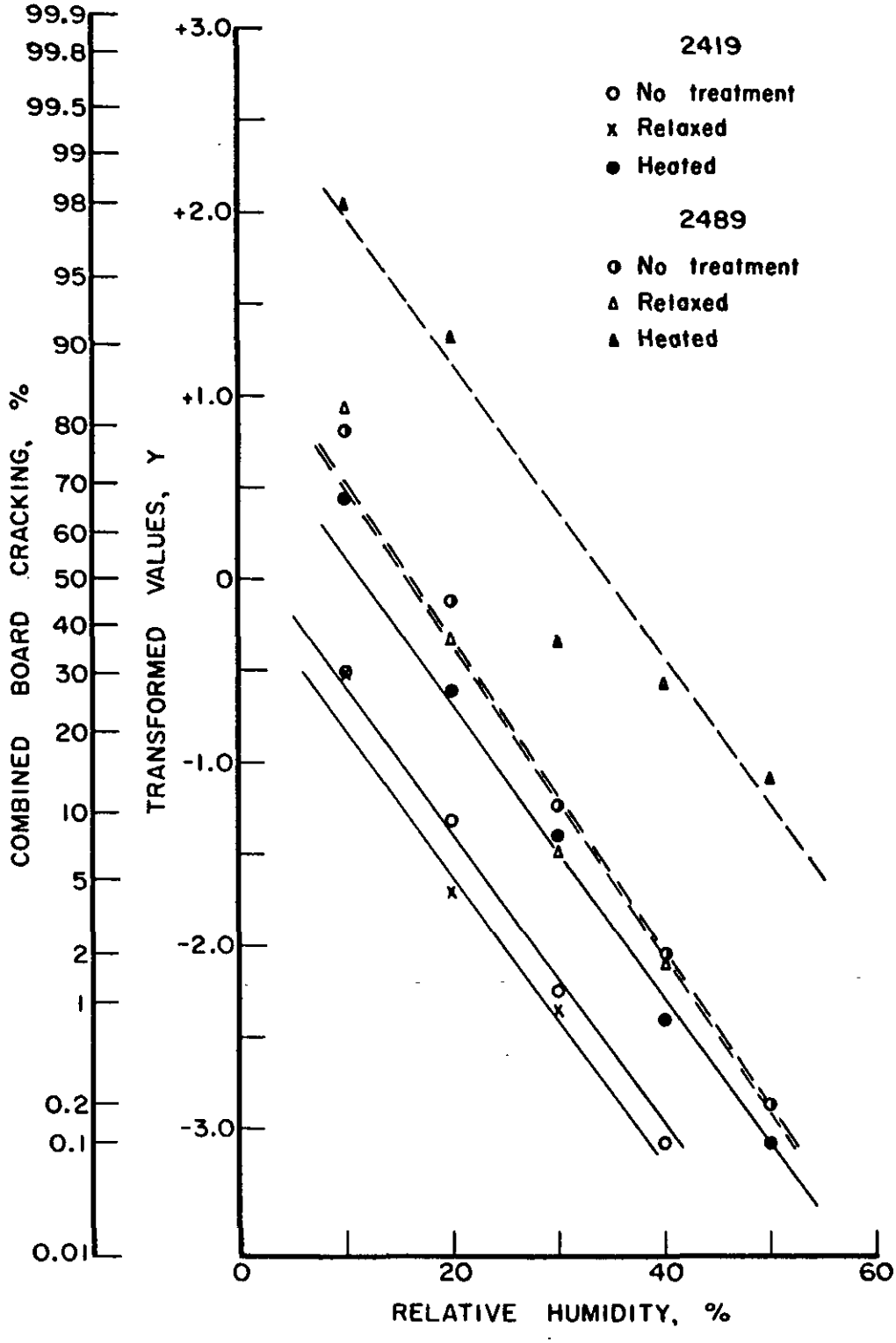

Fig. 3. Effect of Relative Humidity on Combined Board Cracking for Samples 2419 and 2489

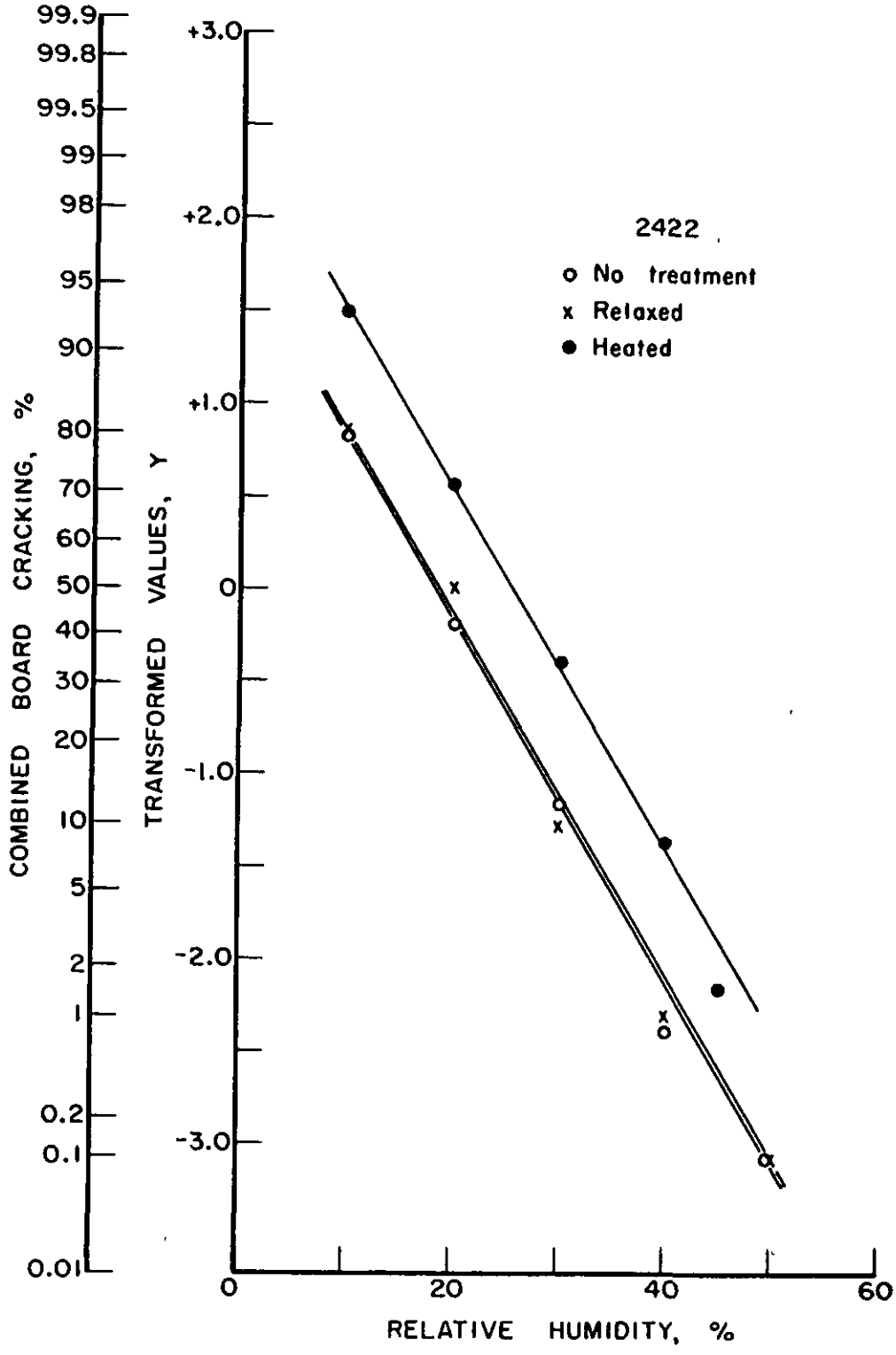

Fig. 4. Effect of Relative Humidity on Combined Board Cracking for Sample 2422

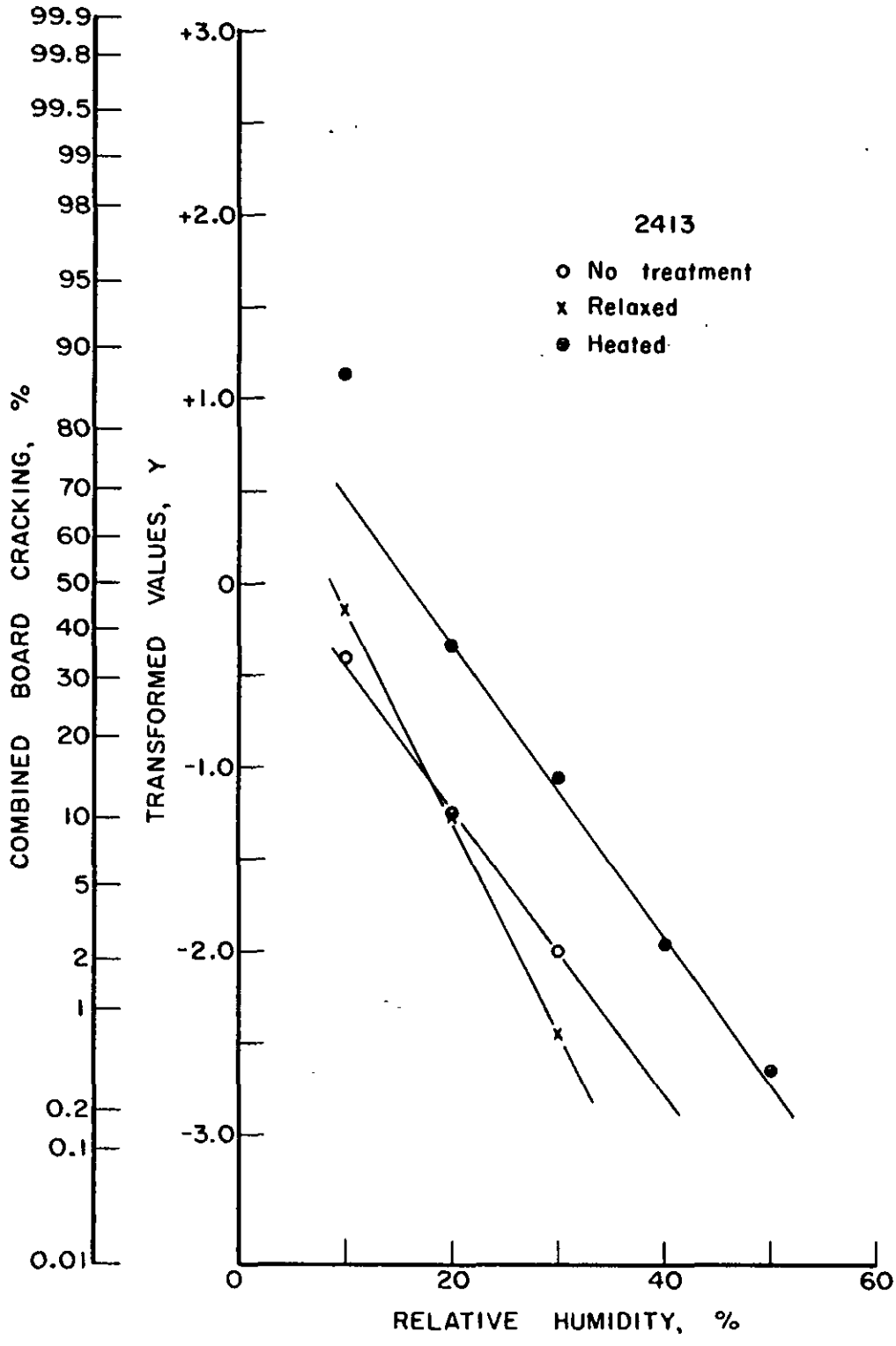

Fig. 5. Effect of Relative Humidity on Combined Board Cracking for Sample 2413

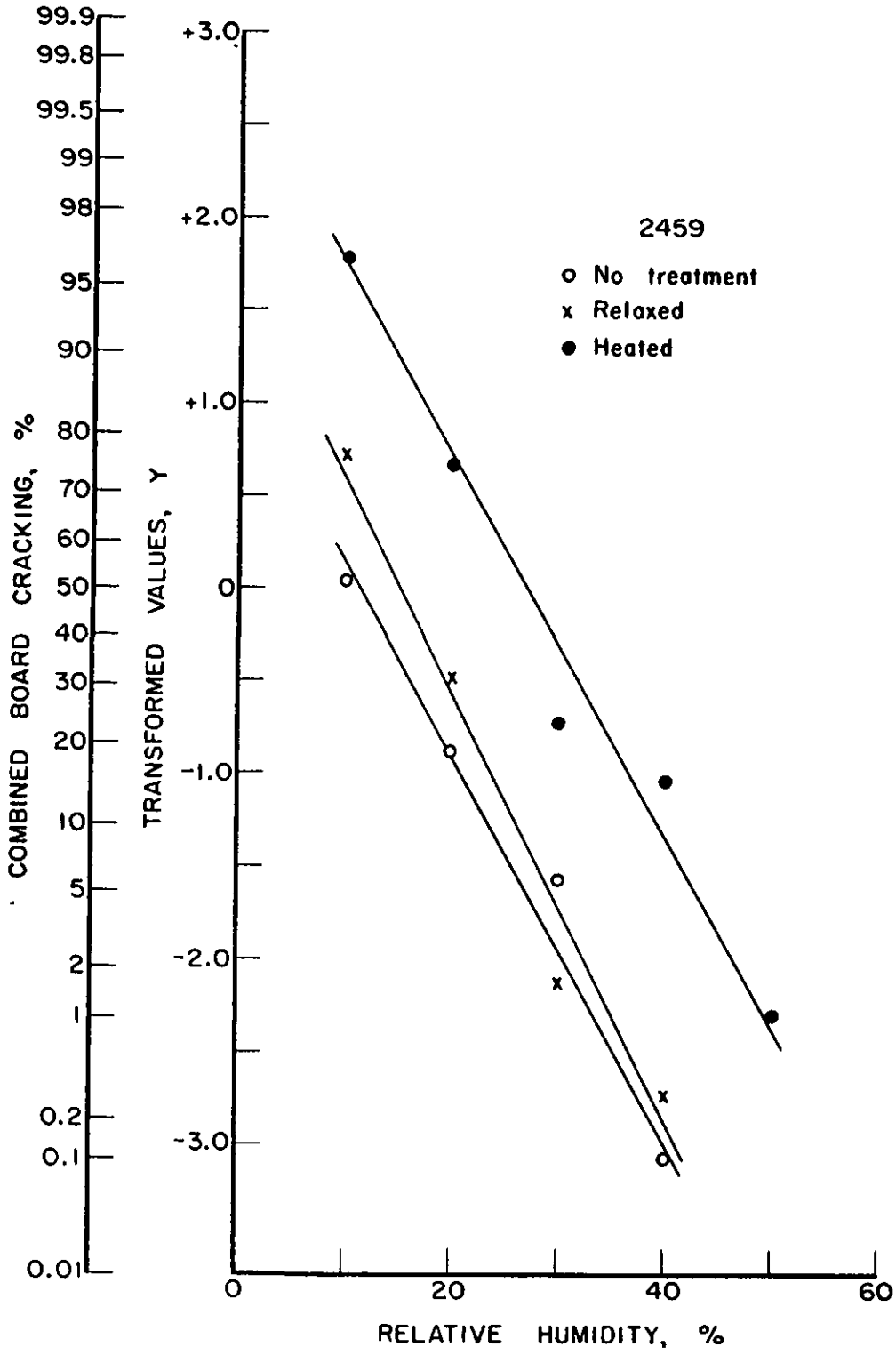

Fig. 6. Effect of Relative Humidity on Combined Board Cracking for Sample 2459

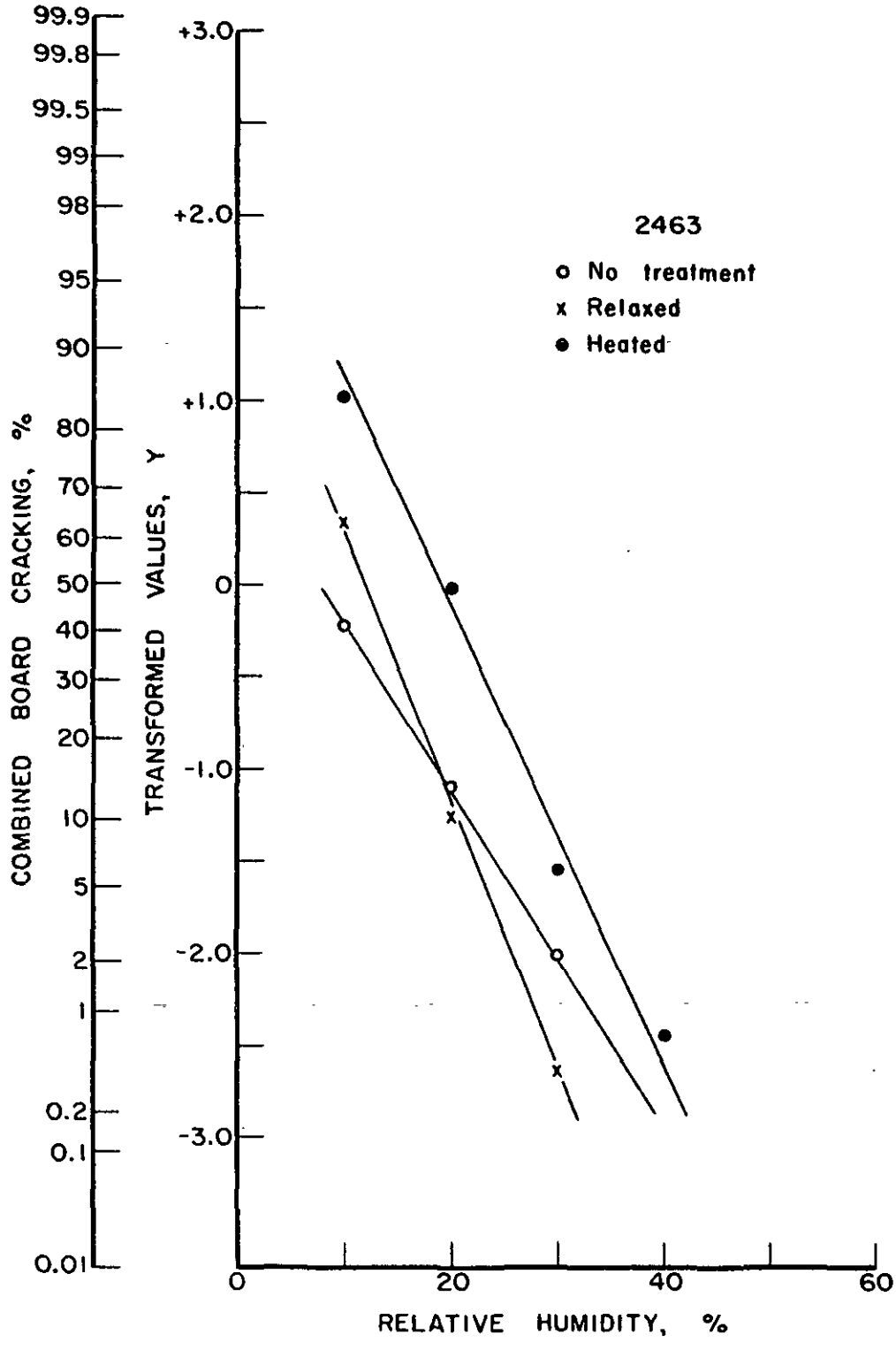

Fig. 7. Effect of Relative Humidity on Combined Board Cracking for Sample 2463

TABLE VII

RELATIONSHIP BETWEEN COMBINED BOARD CRACKING AND RELATIVE HUMIDITY

Sample No.	Data Subdivision	N	Intercept	Slope
2413	Control	3	0.39	-0.0800
	Relaxed	3	1.02	-0.1150
	Heated	5	1.80	-0.0923
2419	Control	4	0.38	-0.0871
	Relaxed	3	0.32	-0.0925
	Heated	5	0.55	-0.0712
2422	Control	5	1.80	-0.1005
	Relaxed	5	1.88	-0.1019
	Heated	5	2.40	-0.0926
2426	Control	4	0.17	-0.0830
	Relaxed	3	0.49	-0.1105
	Heated	5	1.19	-0.0792
2446	Control	5	1.07	-0.0822
	Relaxed	5	0.89	-0.0878
	Heated	5	2.51	-0.0838
2459	Control	4	1.16	-0.1012
	Relaxed	4	1.85	-0.1207
	Heated	5	2.64	-0.0988
2463	Control	3	0.68	-0.0895
	Relaxed	3	1.80	-0.1495
	Heated	4	2.25	-0.1201
2489	Control	5	1.71	-0.0933
	Relaxed	4	1.84	-0.1034
	Heated	5	2.18	-0.0820
Composite		102	1.11	-0.0804
Pooled[a]			1.27	-0.0863

[a]Obtained from an analysis of covariance - IBM program 6.0.032.

Two estimates for an "average" slope are provided in Table VII. The first is based on a regression equation obtained from the array of 102 data points and is equal to -0.0804. The second is a "pooled" value derived from the covariance analysis using IBM program 6.0.032 and may give a slightly better fit to the data. However, for most samples it will make little difference which line is used as is illustrated in Fig. 8.

The over-all regression line for the 90-pound samples is also shown in Fig. 8. In general, the vertical distance between the regression lines for the 90 and 69-pound samples represents the average difference in degree of cracking for the two liner grades for the materials used in these studies. These differences would be as follows using the covariance estimate of the 69-pound regression line.

	Per Cent Cracking	
	69-pound	90-pound
10% R.H.	66	91
20% R.H.	33	69
30% R.H.	10	35
40% R.H.	1.6	10
50% R.H.	0.13	1.6

It also may be remarked that the difference in slope between the 90 and 69-pound grades was relatively small. For many purposes, the difference could be ignored and a graph such as in Fig. 9, Report 2, could be used to estimate cracking at various humidities if the cracking at one humidity level can be estimated, e.g., by making liner cracking tests at one humidity level.

LITERATURE CITED.

1. Grant, E. L. Statistical quality control. 1st ed. New York, McGraw-Hill Book Co., 1946.

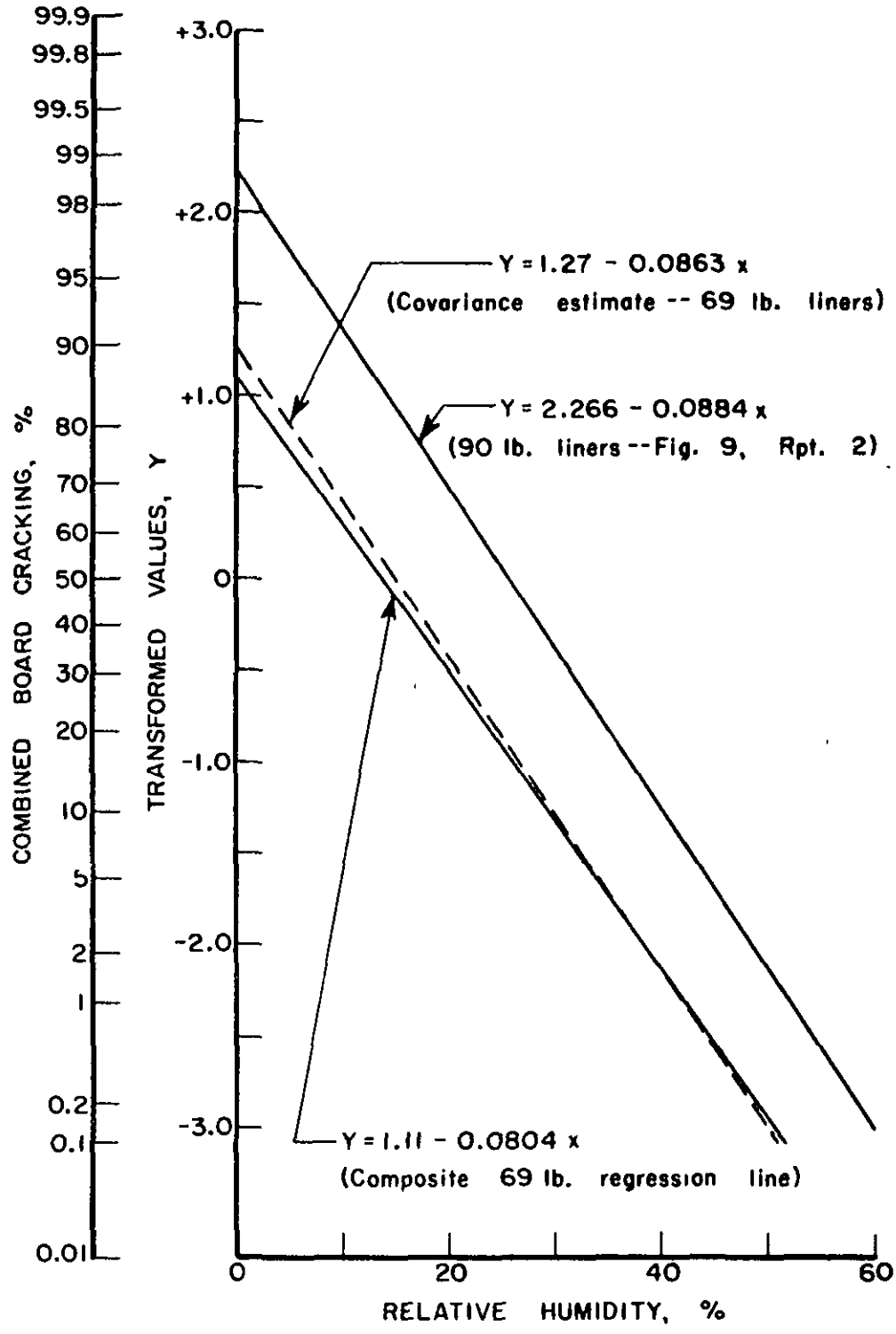

Fig. 8. Comparison of Regression Equations for Relationship Between Combined Board Cracking and Relative Humidity

APPENDIX I

COMBINED BOARD CRACKING PERCENTAGES TRANSFORMED TO NORMAL DEVIATE VALUE

Sample No.	Combined Board Cracking, transformed[a] 10% R.H.	20% R.H.	30% R.H.	40% R.H.	50% R.H.
			Untreated		
2413	-0.40	-1.24	-2.00	--	--
2419	-0.50	-1.32	-2.26	-3.09	--
2422	+0.83	-0.20	-1.18	-2.41	-3.09
2426	-0.73	-1.29	-2.51	-3.09	--
2446	+0.29	-0.32	-1.73	-2.46	-2.75
2459	+0.05	-0.88	-1.58	-3.09	--
2463	-0.22	-1.09	-2.01	--	--
2489	+0.81	-0.10	-1.23	-2.05	-2.88
			After High Humidity Relaxation		
2413	-0.15	-1.25	-2.45	--	--
2419	-0.51	-1.73	-2.36	--	--
2422	+0.84	0.0	-1.29	-2.33	-3.09
2426	-0.54	-1.87	-2.75	--	--
2446	+0.10	-0.69	-1.93	-3.09	-3.09
2459	+0.72	-0.49	-2.15	-2.75	--
2463	+0.34	-1.26	-2.65	--	--
2489	+0.95	-0.32	-1.51	-2.10	--
			After Drying at 125°C. for 36 Hours		
2413	+1.15	-0.33	-1.06	-1.96	-2.65
2419	-0.43	-0.61	-1.41	-2.41	-3.09
2422	+1.49	+0.57	-0.40	-1.37	-2.17
2426	+0.43	-0.18	-1.61	-1.94	-2.65
2446	+1.58	+0.95	-0.02	-0.77	-1.75
2459	+1.80	+0.66	-0.73	-1.04	-2.29
2463	+1.03	-0.02	-1.56	-2.46	--
2489	+2.07	+1.32	-0.35	-0.56	-1.09

[a]Transformed to normal deviate values using Table A, Appendix III of Reference (1).